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Impact of conservation tillage on soil quality and crop yield in the cold region of northwestern Canada

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Summary

For the past several years, our research, and numerous studies elsewhere, have shown that with continuous no-tillage soil organic matter increases, soil structure improves, soil erosion is controlled, and with time crop yields are maintained or even increase significantly from what they were under intensive tillage. In this paper we have compiled data from several long-term studies in northern areas of western Canada to demonstrate the impact of no-tillage (NT) management on yields of spring crops (cereals, pulses and oilseeds) and soil quality as compared with conventional tillage (CT). Chemical (soil organic matter), physical (water storage, aggregate stability) and biological (N mineralization, microbial biomass, and diversity) indicators of soil quality suggest improvement under NT management.

Keywords: Tillage and soil quality, Barley, Canola, Pea, Wheat, Microbial diversity

Introduction

No-till farming conserves energy. Adoption of this practice can significantly curtail water and wind erosion often caused by intensive tillage which results in deterioration of soil, water and air quality. Numerous studies comparing CT vs NT practices have been conducted worldwide with varying degree of success. A review of conservation tillage systems (types, equipment etc) and their effects on soils and crops can be found elsewhere (Unger, 1990).

The objectives of this paper are (i) to summarize the results of tillage research conducted at five sites in northwestern Canada and (ii) to assess the impact of conservation tillage and crop management systems on crop yield and soil quality in cold regions.

Materials and methods

Soils managed under CT and NT for 4-16 yr were collected from four locations in northern Alberta and British Columbia. Details on location, soil, crop rotations, and design are listed in Table 1. Mean annual temperature is 1-2 °C and mean annual precipitation is 450-500 mm. Conventional tillage consisted of one fall tillage with a cultivator equipped with chisels spaced at 200 mm and a working depth of 100-150 mm, followed by two cultivations (80-100 mm depth) in the spring prior to seeding. No-tillage consisted of harrowing following harvest to evenly distribute straw and spraying glyphosate to control weeds prior to seeding.

The BIOLOG system (Biolog, 1993) was used to determine diversity and community structure of soil bacteria with substrate utilization. Our method for inoculating Biolog plates was adapted from Zak et al (1994) and is described by Lupwayi et al.(2001). Readers are referred elsewhere for details of methods for aggregate stability and soil organic C (Franzluebbers & Arshad, 1996), microbial biomass and mineralizable C and N (Franzlubbers & Arshad, 1997).

Results and discussion

Tillage effects on crop yield

A summary of data showing the effects of NT vs CT on yields of spring barley (*Hordeum vulgare* L.*)*, wheat (*Triticum aestivum* L.), canola (*Brassica campestris* L.), and pea (*Pisum* *sativum* L.) at the five sites studied is presented in Table 2. Yields of all crops varied greatly from year to year and at different sites, as is evident from a wide range observed among the sites (Table 2). There was a significant increase in barley (14 %) and pea (22 %) yields under NT than CT management. Significant increases in yields of canola and first wheat crop (W1), at the Leith sandy loam site for example (fig.1a), were also recorded when grown in rotation, especially with a preceding legume crop. Wheat yield following field pea was greater by 6% than wheat following fallow. Including legumes in rotation reduced the incidence of root diseases compared with continuous wheat, both under NT and CT management.

Tillage effects on soil quality

Significant improvements in organic C (fig. 1b) and aggregate-size distribution (fig. 1c) occurred under NT compared with CT at 0-50 mm soil depth. Higher water storage under NT than CT (Table 3) may have contributed to higher biological activities and greater aggregate stability. Our previous results (Franzluebbers & Arshad, 1997) indicated that microbial biomass and

Table 1. *Description of experimental conditions of the five field study sites.*

Property	Donnelly loam	Donnelly silt loam	Hythe clay loam	Falher clay	Leith sandy loam
Location	55° 42' N, 120° 10' W	55° 46' N, 120° 21' W	55° 11' N, 119° 32' W	55° 43' N, 118° 41' W	58° 23' N, 116° 02' W
Soil classification (Canada)	Gray Luvisol	Gray Luvisol	Gray Luvisol	Solodized Solonetz	Gray Luvisol
Soil classification (US)	coarse-loamy, mixed, frigid Typic Cryoboralf	fine-loamy, mixed, frigid Typic Cryoboralf	fine, montmorillonitic frigid, Mollic Cryoboralf	fine, montmorilloniti c frigid, Typic Natriboralf	coarse-loamy, mixed, frigid Typic Cryoboralf
Clay (%, 0-200mm)	18	28	37	63	12
Silt (%, 0-200mm)	46	51	41	31	21
pH (0.01M $CaCl_2$)	6.6	5.5	5.1	5.7	5.6
Initiation of study	1988	1979	1991	1989	1992
Crop sequence	W-Ca-B [z]	CB	B-Ca-B	B-F-Ca-W	P-W1-Ca-W2 RC-W1-Ca-W2 F-W1-Ca-W2 CW
Experimental design	paired plots in adjacent fields	paired plots in adjacent fields	randomized, block	randomized, block	randomized, block
Plot size (m)	20 x 50	20 x 50	3 x 15	12 x 39	3.6 x 25
Replications	4	3	4	4	3

[z] W = wheat,W1=first wheat crop,W2=second wheat crop, Ca = canola, P = pea, F = fallow, RC = red clover, CB = continuous barley and B = barley

mineralizable C were greater in larger aggregates (found in NT than CT) due to protection of organic C by soil aggregates. Diversity of soil bacteria was greater under NT than CT (fig.1d), and greater in larger soil aggregates, during the crop cycle.

Concluding remarks

We have compiled a great deal of evidence to conclude that continuous no-tillage and legume-based cropping systems are the most effective and practical approaches for restoring and improving soil quality, which is vital for sustained food production and a healthy environment.

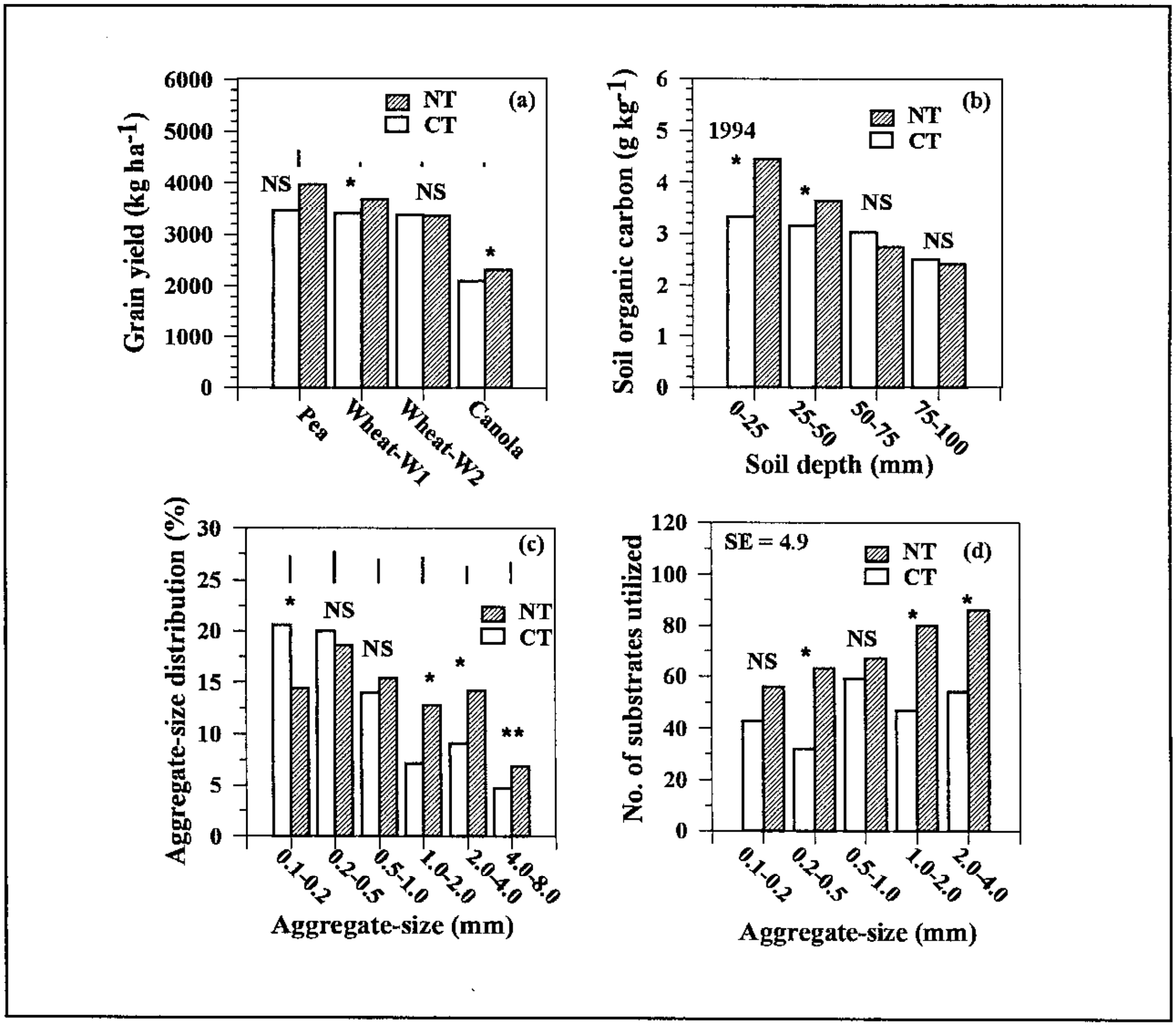

Figure. 1. (a) Mean crop yield (1993-1996) at the Leith sandy loam soil as affected by no-till(NT) and conventional tillage (CT) systems. Vertical bar indicates ± 1SE.
(b) Organic C in Donnelly loam soil as affected by tillage and soil depth in 1994.
(c) Impact of tillage system on soil structure (aggregate-size distribution) in Hythe clay loam in 2001. Vertical bar indicates ± 1SE.
(d) Interaction of tillage and soil aggregate class in number of substrates (microbial diversity) utilized in Donnelly silt loam at barley-heading growth stage in 1995.
NS and * indicate not significant and significant at 0.05 probability level, respectively.

Table 2. *Crop yield under no-till (NT) vs conventional tillage (CT) at sites located in northwestern Canada*

Crop	Year	Site years	Yield ($kg\ ha^{-1}$) CT (Range)	NT (Range)	Difference (%)
Barley	1979-1996	31	2171b[z] (1630-3420)	2478a (1980-3700)	14.1
Wheat	1991-1996	13	3240a (2442-3750)	3267a (2494-3670)	0.8
Canola	1991-1996	16	1417a (1018-2090)	1413a (875-2310)	0.3
Pea	1993-1996	10	2975b (2490-3460)	3645a (3320-3970)	22.5

[z] Means followed by the same letter are not significantly different from each other ($P \leq 0.05$).

Table 3. *Mean soil water contents(averages of 45 in 1992 and 33 measurements in 1993) in Donnelly silt loam under no-till (NT) and conventional tillage (CT)*

Depth (cm)	NT	CT	NT	CT
	($m^3\ m^{-3}$)			
	15 May to 9 Sep. 1992		7 June to 16 Aug. 1993	
0-15	0.22a[z]	0.15b	0.38a	0.22b
15-30	0.23a	0.18b	0.39a	0.32b
30-45	0.27a	0.19b	0.43a	0.30b
52.5-67.5	0.28a	0.21b	0.40a	0.32b

[z] Means for the given year followed by the same letter in the row do not differ significantly at $P \leq 0.05$.

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